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Feasibility study for establishing an automated data base system for Naval Electronics Engineering Center, Vallejo.

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FEASIBILITY STUDY FOR ESTABLISHING AN AUTOMATED DATA BASE SYSTEM FOR NAVAL ELECTRONICS ENGINEERING CENTER, VALLEJO

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Monterey, California

THESIS

FEASIBILITY STUDY FOR ESTABLISHING
AN AUTOMATED DATA BASE SYSTEM
FOR
NAVAL ELECTRONICS ENGINEERING CENTER, VALLEJO

by

James Edward Tarver

June 1975

Thesis Advisor: S. H. Parry

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Feasibility Study For Establishing An Automated Data Base System For Naval Electronics Engineering Center, Vallejo

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the requirements for the degree of

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ABSTRACT

The purpose of the feasibility study is to establish an automated data base system for Naval Electronics Engineering Center, Vallejo, California. The three divisions, namely, the financial, procurement and program manager's divisions, were analyzed as a separate entity by taking their present methods of operation and determining which methods lend themselves to automation and propose a conceptual EDP system to handle the new data structure. After combining the applications of each division, a file design structure along with the associated hardware equipment and recommendations for further evaluating the overall performance of the system were supplied for NAVELEX.

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I. BACKGROUND AND GENERAL PROBLEM STATEMENT

The Naval Electronics Systems Engineering Center (hereafter referred to as NAVELEX), Vallejo, California is tasked with the mission of providing electronics material support for electronic systems and individual equipment onboard ships and government field activities as assigned by the Naval Electronics Systems Command. The majority of work performed on these electronic pieces of equipment is accomplished by reimbursable work (e.g. the sponsoring activity of the particular ship or field activity sends an allocation of money for the work that NAVELEX is to perform). Thus, there is no operating budget from appropriated funds to sustain their operation, funding being provided only from the various sponsoring activities. Though NAVELEX has an accounting section for internal budgeting, the authorizing accounting activity (AAA) for reporting NAVELEX's budget to higher authority is the responsibility of NSC Oakland. In addition, NSC Oakland is responsible for the contracting of items with a value over $250.

To assist the commanding officer in accomplishing the above stated mission is the task of the Planning and Program Management and Engineering departments respectively. The Planning and Program Management department responsibilities include advance planning on major task assignments, financial management and material management for all elements of the command and the command itself, and for the planning required for the development and support of budget, long range, emergency and other command plans. These responsibilities and tasks are further divided among three divisions. These divisions

presently conduct their business without the aid of automation and are the subject of the feasibility study presented later in the paper. The Engineering department is responsible for the technical design, development and systems engineering on all task assignments and for the maintenance of plan files and for library and reproduction services. The Engineering department was not considered in the feasibility study because it was determined in the preliminary investigation that computer terminals already existed as an aid to attaining its goal. The only problem with the system as it now exists is that there is no hardcopy capability. All data is input on a display terminal to the computer facility at Lawrence Berkley Laboratories (LBL) and the computer printout is mailed to NAVELEX. If a telephone line hook-up was established between LBL's computer and a line printer at NAVELEX, the problem of meeting the time constraints imposed by the different task projects would be satisfied.

NAVELEX's two departments were faced with the problem of improving their response time and thereby increase their effectiveness in the areas of material status for all assigned tasks, various accountability reports, and for the maintenance of plan files. To determine what the impact of automating some of their present techniques would have in solving their problem, a feasibility study was conducted. The study was restricted in the sense that any computerized system conceived would have to be operated by in-house personnel due to a government freeze on hiring. This caused additional factors to be considered. The personnel selected to operate the system would have to be retrained. The impact this retraining would have on the operation of the system by switching from a manual operation to a mechanized operation must be considered. These factors are not discussed

in the thesis but are merely mentioned to acquaint the manager with the possible pitfalls that lie ahead.

Since no generally accepted procedure exists for determining what steps to follow in conducting a feasibility study, the choice of steps selected for each division in the Program and Planning Management department was to determine the required reports that had to be generated by their present methods of operation, what methods lend themselves to automation and to produce an electronic data processing system (EDP) to handle the new automated techniques. Chapter two discusses the financial division, Chapter three describes the procurement division and Chapter four discusses the operation of the program manager's division. Chapter five combines all three divisions in the analysis of file organizations and produces a conceptual system for the Planning and Program Management department. In addition, recommendations are presented for further evaluation of the overall effectiveness of the system.

II. FINANCIAL DIVISION

The financial division is responsible for preparing financial reports for the procurement division and for their submission to the authorizing accounting activity (AAA), NSC Oakland, and for supervising timekeeping and payroll opertions. The following sections all discuss the two functions of the financial division namely, payrolls and contracts.

A. PAYROLL OPERATION

The present method of handling payrolls consists of each shop center submitting a weekly worksheet to the financial payroll section that contains all the hours earned for that week including leave hours, sick hours, and assignment to temporary additional duty of their personnel. (Presently there are 790 employees assigned to NAVELEX). Once in the financial division, two personnel are assigned to transcribe the hours from the worksheet onto time cards and to validate any overtime. Overtime must be validated because salaried employees are not allowed overtime whereas hourly employees are allowed overage. This normally takes two working days before the time cards are routed to the accounting section. The accounting section deducts the total dollar amount that the employee worked on a particular job order (at anytime there are at least 800 job orders outstanding) from the balance of the allotted dollars assigned to that job order. If the employee worked on a number of different job orders during the week, it is possible that his time card would have to be processed by two or

more accountants, since each accountant is responsible for only a fraction of the job orders that the financial division has outstanding. After all the time cards have been verified and posted to the accounting ledgers, they are sent to NSC Oakland where they are then keypunched and listed onto two magnetic tapes. One tape is retained by NSC Oakland to update their accounting records for reporting to higher authority since they are the designated accounting activity for NAVELEX, Vallejo. The second tape is forwarded to the Regional Disbursing Center at Treasure Island where the employees' checks are actually printed. After all of the checks have been printed, a designated person from the financial division receipts for the checks and issues them to the various shop centers. This entire cycle is then repeated for the next week's worksheet.

The problem that the financial division has with the above procedure is that of getting the time cards to Oakland in a timely fashion; in effect they are faced with improving their response-time while at the same time retaining some semblance of in-house accountability control. The problem of timely reporting is caused by the nature of work performed by the employees. One employee may work on as many as five different job orders during the week thereby requiring his time card to be processed by two or more accounting personnel. This can cause a delay of two additional work days before the total package of time cards are ready for submission to NSC Oakland.

Analysis For A Conceptual EDP System

The realization of an improved method of solving the dilemma that faces NAVELEX Vallejo required an evaluation of their input,

data base, output and processing requirements. Input requirements could encompass a large area, but since this portion of the study was concerned with reviewing the payroll operation, the only areas that were considered for implementation in the computer system were the media, frequency of input, format of the input, and the type of transactions. The data base requirements considered the list of data elements including whether the elements were alphabetic, numeric or alphanumeric, indexing the entry into the data base, and the format of the data base. In regard to output requirements, the study considered the output media, the retrieval mode, format, and the output descriptors. Lastly, the processing requirements analyzed consist of the type of arithmetic operations required. The different operations required to get useful and meaningful output would consist of searching, sorting and editing.

To formulate the input requirements, it was determined that all the time cards had to be processed at the end of each week and further that the most important information (as far as the accounting section is concerned) is the dollar amount and number of hours credited to the employee while working on a particular job order. In order to incorporate these two requirements, it was decided to use a batch schedule to update the master file and to run the required weekly update. The decision to employ a batch system vice a time sharing system as based on the fact that the employee's work sheet is only completed at the end of the week, thus precluding any daily update to the file. The input media used consists of punched cards, which gives the flexibility of having a direct visual copy of what was input into the system in case the system

is down or that an error is deteeted. The input format, shown in figure 1, avoids having to input the entire reeord for each updatc. The type of transaetions involved would be the ehanging of fields (e.g., inereasing the hourly rate field if an employee reeeived a raise or deleting entire records in the case that an employee was dropped from employment). Also, an option was left to increase the size of the master file. This option satisfied the addition requirement of the input.

SOCIAL SECURITY NUMBER	JOB ORDER NUMBER	HOURS WORKED	EMPLOYEE'S NAME

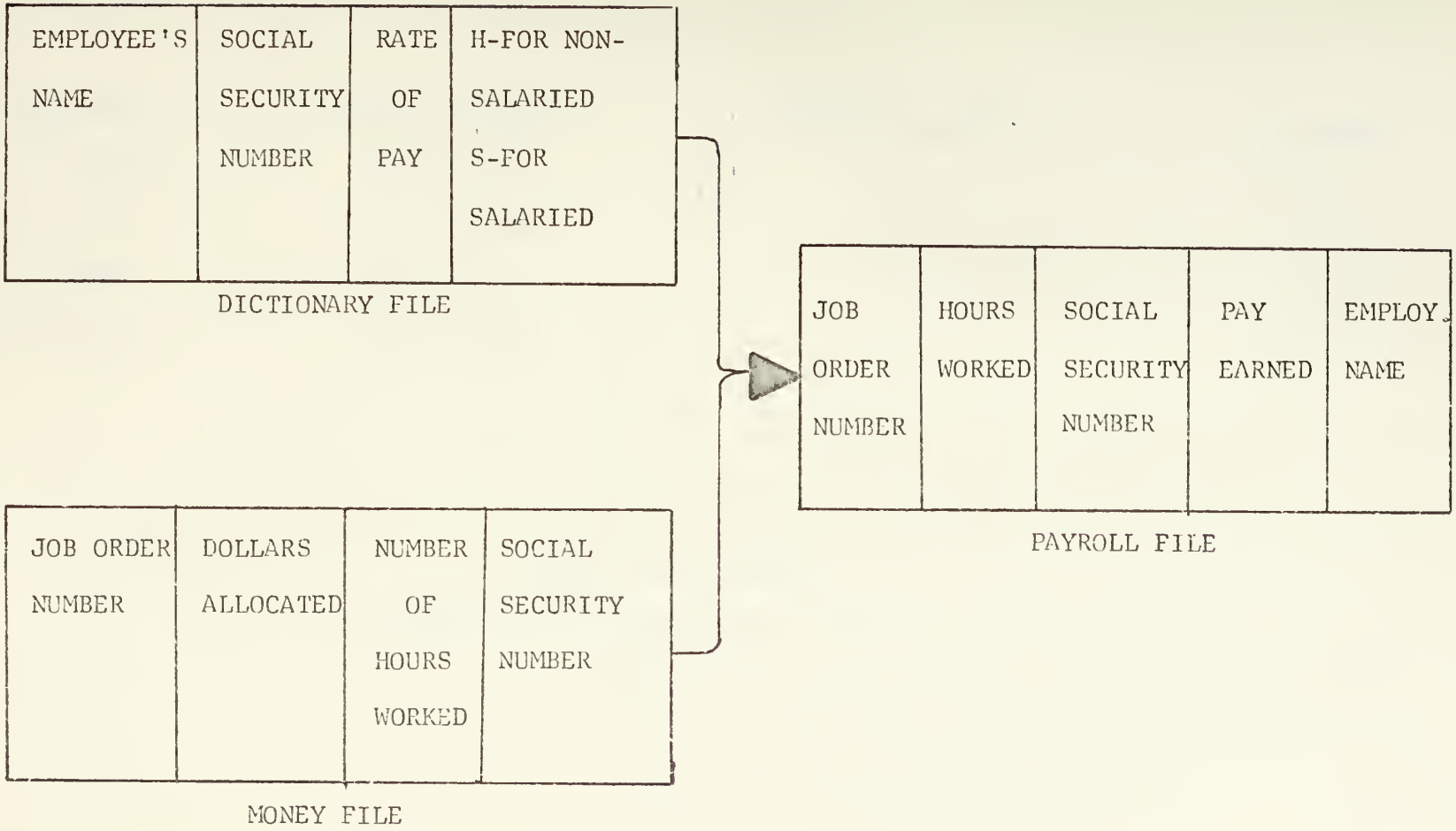
DATA INPUT

Figure 1

The data base had to bc structured so that pertinent information required by thc aceounting seetion eould be readily attainable. This was aeeomplished by having two data files that arc merged forming a "Payroll" filc. One data file is called the "Dictionary" file which consists of the following data elements: employees' name arranged in alphabetie order, social security number of the employee, and the hourly rate of pay if the employee is an hourly worker or the salary rate if the employee is salaried. The seeond data file is called the "Money Order" file whose eomposition is job order number, dollars alloeated (which is the total dollars alloeated for that job),

number of hours worked, and the social security number of the employees who worked on that particular job order. These two files are then merged to produce a master file called a "Payroll" file. The format for these data structures is shown in figure 2. It is obvious that the "Payroll" file (see figure 2) must consist of the following data elements: name, social security number, number of hours worked and the rate of pay, since this is the information that NSC Oakland requires for accounting purposes. The contents of all the data files are both numeric and alphanumeric.

The output information required by the accounting section must be in a readable and usable form. The simplest media for obtaining this output is to have a hard copy capability that is supplied by a low-speed printer. A low-speed printer was decided upon vice a medium or high speed printer because of the cost involved, since the output does not have to be retrieved rapidly. A likely output format would key on the job order number field listing the job order in sequential order and within this job order an alphabetical ordering of the employees' names, with the number of hours each employee worked. A sample output listing is given in figure 3. There are various options for outputting the data. As mentioned earlier one report would be in job order sequence and another by alphabetical sequence of the employees' name. An example of this report is shown in figure 4. The output retrieval mode would have to be by batch keying on multiple descriptors.



FINANCIAL DIVISION FILES

Figure 2

JOB ORDER NUMBER: LMC 04512

EMPLOYEE NAME	SOCIAL SECURITY	NUMBER OF HOURS	PAY EARNED
Anderson, John	432-10-6546	5	$ 98.50
Boldie, Benny	483-20-0405	8	150.30
Durry, James	698-00-0936	2	32.00
Wade, Sherman	999-09-5406	40	280.00

SAMPLE DATA OUTPUT

REMAINING UNUSED DOLLARS: $19,054.00

Figure 3

EMPLOYEE'S NAME: Anderson, John

JOB ORDER NUMBER	HOURS WORKED	ALLOCATION REMAINING	RATE OF PAY
LMC 04512	8	$ 19,054	$46.00
LOC 5555	6	150,000	32.00
LCC 9321	12	50,000	69.00

SEQUENTIAL OUTPUT

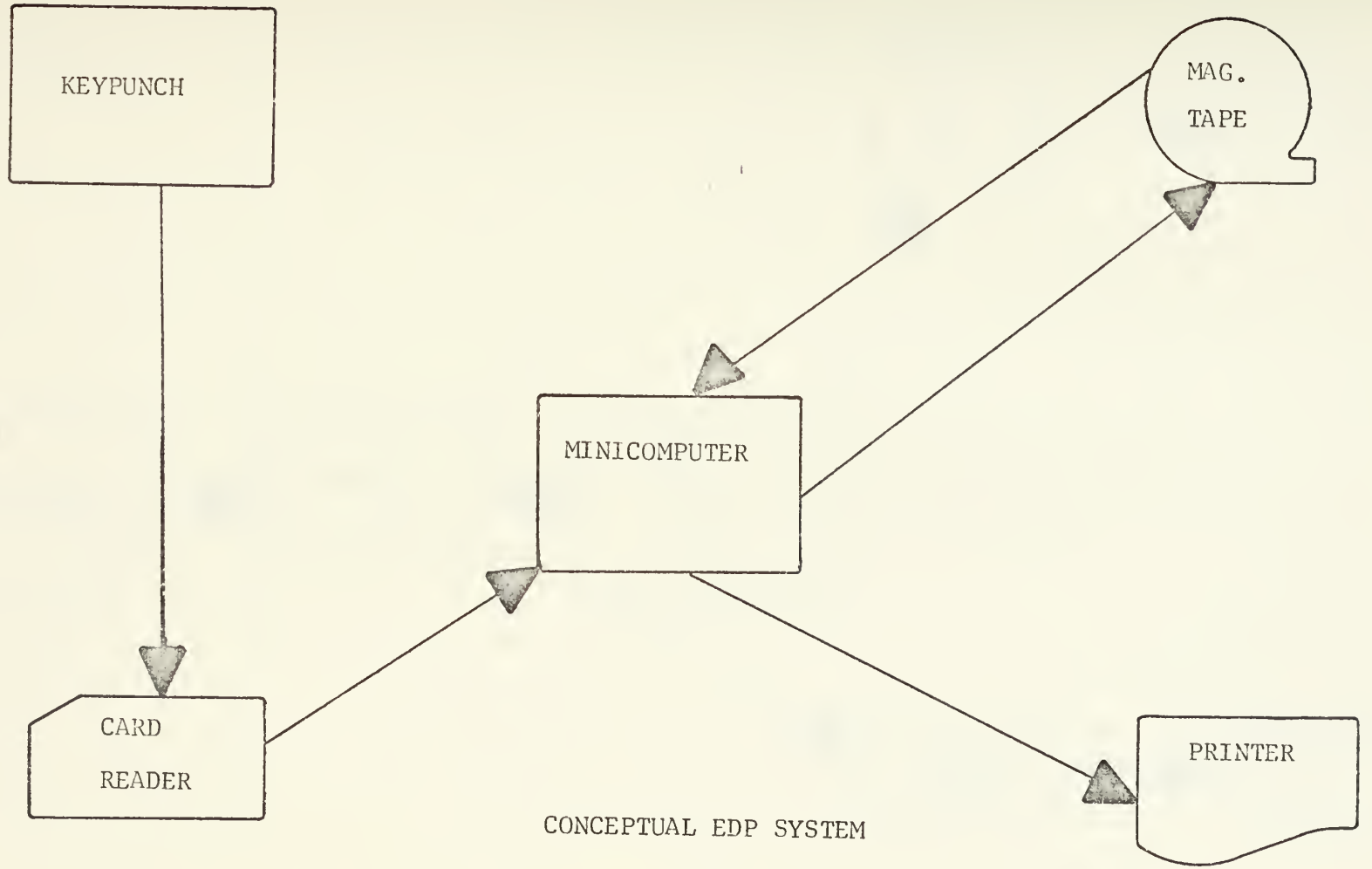
WEEKLY PAY EARNED: $147.00

Figure 4

The processing requirements must include the capability of sorting records either by name, social security number, job order number, etc. Also, if any changes are made to a record it is desirable that only selected fields be edited without having to input a complete new record every time a change is made. Therefore this feature must be added to the system. The search of the file is done sequentially.

Using the above analysis, a conceptual EDP system is illustrated in figure 5. A detailed analysis of the file structure required to implement the system is given in Chapter five. This operation would be based on having the shop center supply a person to validate all overtime and leave of personnel assigned to their centers. This person would keypunch the time cards and submit them to the computer. The computer would produce a magnetic tape for NSC Oakland and a listing printout for the financial division's in-house use (see figure 6). This automated procedure would eliminate at least four working days from the present manual processing time.

To handle this procedure, the system would not require a large memory capacity so a minicomputer with a capability of add-on memory could be used. Since NAVELEX is concerned with getting the magnetic tape to Oakland as soon as possible (and at the same time retaining a hard copy to validate internal control), a medium speed magnetic tape unit for rapidly producing tapes, a low-speed offline printer for producing a hard copy to be retained by the financial section and a card reader to read the input are required.

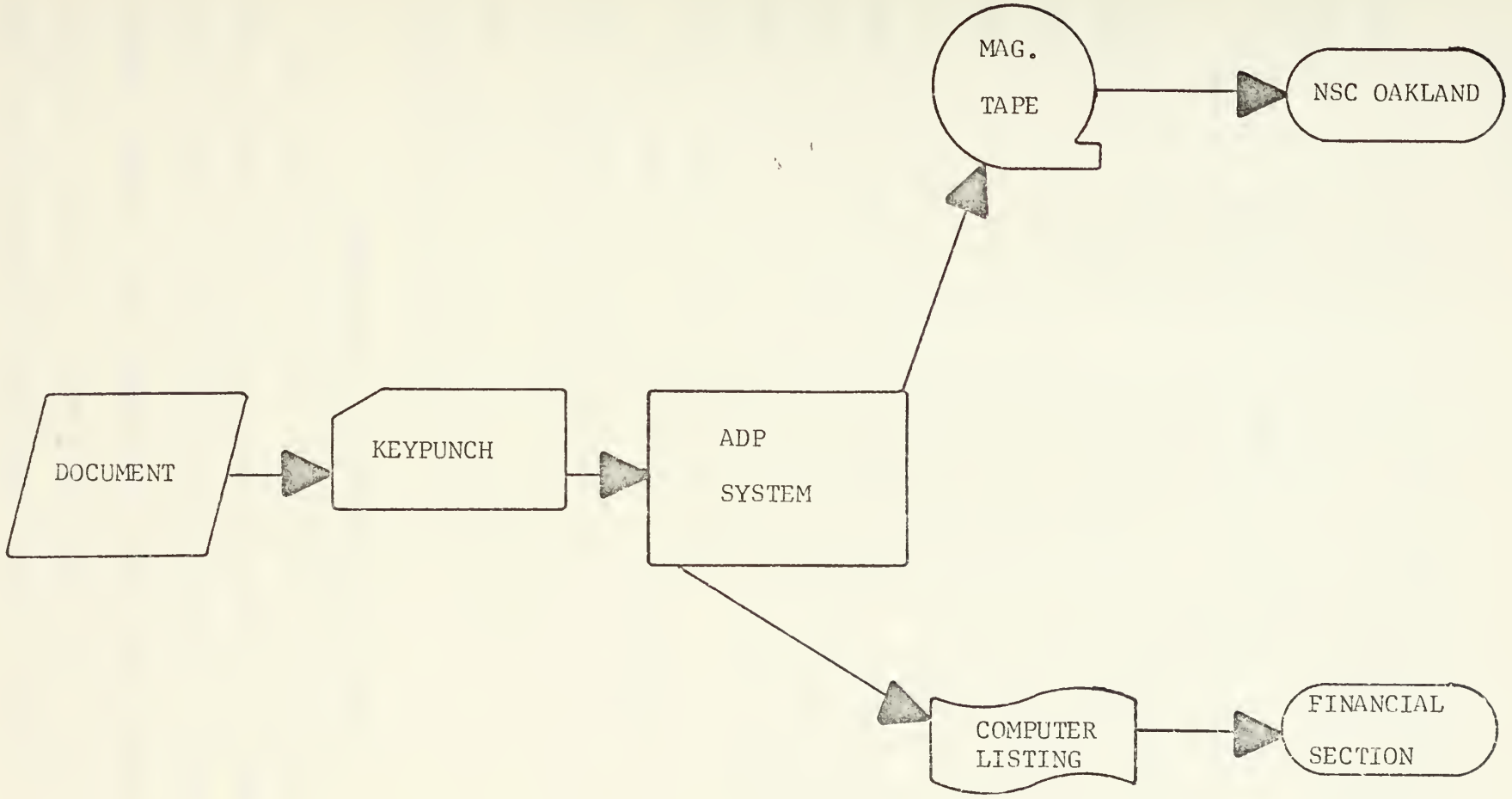


CONCEPTUAL EDP SYSTEM

FOR

FINANCIAL DIVISION

Figure 5



FINANCIAL DIVISION

DOCUMENT FLOW

Figure 6

B. CONTRACTS

Contracts fall into two basic categories, Indefinite Delivery and One Time Purchase contracts. In this chapter Indefinite Delivery will be discussed because it is the only type of contract that the financial section handles directly.

Indefinite Delivery contracts are contracts that have already been established with a contractor due to some previous demand experience or request. Once the decision is made by the project manager that contract support is required, the financial management division is responsible for administering financial control of the contract request which consists of assigning a requisition number and obligating funds against that job order and for sending the obligation to NSC Oakland, and for effecting purchase action which calls for the contractor to give a dollar amount estimate for the requested material or services.

The problem that the financial section faces is to assure that reported outstanding obligations are, in fact, outstanding and if the material or services have been received to make sure that receipts are posted in a timely fashion so that payment to contractors can be effected.

Analysis For A Conceptual EDP System

The above problem cannot be solved by the financial division alone because they depend on the shop centers to provide signed receipt copies to effect payment. In addition, the financial division relies on the procurement and planning division to provide the status of outstanding requisitions. Since the requirements for the conceptual EDP system are very similar to the EDP

requirements for the contract portion of the procurement and planning division, an alalysis for the financial division will be delayed and combined in the analysis of the procurement section of contracts discussion.

III. MANAGEMENT ANALYSIS AND ADVANCE PLANNING DIVISION

The management analysis and advance planning division will be hereafter referred to as the procurement division since this is the only portion of the operation that a request for a feasibility study was made. The procurement division has the responsibilities for the establishment of NAVELEX's annual Indefinite Delivery contracts, for initiating One Time Purchase contracts through the appropriate procurement contracting office, NSC Oakland, and for the surveillance and administration of the contract after award. The remaining paragraphs of the chapter will discuss the present method of operation, the problems associated with the method and offer an alternative approach to enlarge the overall effectiveness of the division's operation.

A. PROCUREMENT DIVISION OPERATION

The basic decision of whether contractor support is required on a particular job order rests with the shop center responsible for the work associated with the job order. Where contractor support is desired, or required, a contracting specialist is available in the procurement division to provide contracting advice. The contracting specialist reviews the request from the shop center and forwards the document to the financial division where it is verified that funds are either available or exhausted

for the job order. If funds are available after verification the contracting specialist prepares the necessary procurement request to the contracting office (usually, NSC Oakland) if the request is for a One Time Purchase. If the request can be filled with an Indefinite Delivery contract no assistance from NSC Oakland is required. When the request is forwarded to NSC Oakland, the contracting specialist must then await a reply from the contracting office before any action can be taken. However, the procurement division's contracting specialist maintains liaison with the contracting office as required to assure any questions that may arise are answered and to assist the contracting officer throughout the preawarding process. When the contract has been awarded, copies are provided to the shop centers concerned to assure consistency with the original requirements. When changes are required to an existing contract, the shop center will initiate the request and it will be routed through the program manager, procurement division, financial division for accounting purposes, and finally to the contracting office. If immediate changes are required, the program manager is notified. He works with the contracting specialist who advises the applicable contracting officer to inform him of the immediate action required. With the contracting officer's approval, the change is then accomplished and the paper work follows. In the case of Indefinite Delivery contracts, the contracting specialist goes directly to the contractor with the request and monitors the request until the material or services are delivered. After the receipt of the materials, the contracting specialist determines the quality and acceptability of

the materials and passes the information to the financial division so that the contractor may be paid.

The primary problem facing the procurement division is the need to shorten the response time from the shop center's initial request for contractual services until the contracted material is received. An additional drawback is the inability of NAVELEX to contract directly (without going through the contracting office, NSC Oakland) any One Time Purchase contract with a dollar amount exceeding $250. This factor is a substantial restriction for NAVELEX's operation because most of the contract requests are in the range of fifty thousand dollars.

Unless NAVELEX is authorized a larger dollar ceiling there will always be a significant time delay. This delay occurs because the document requesting contract support must be mailed to NSC Oakland and normally there will be additional delays because of constant telephone communications with the contracting officer at Oakland trying to obtain information from the contracting specialist. The only portion of the problem that NAVELEX can influence is the currency of the Indefinite Delivery contract and of providing current status of One Time Purchase contracts.

Conceptual EDP System For Procurement Division

The purpose of the feasibility study is to investigate alternative methods to minimize the response time from the initial request for contractor support until the receipt of the material from the contractor. As noted from the above operation, the only influence that the procurement division can bring to bear on the problem is to validate the currency of the annual

Indefinite Delivery contracts so as to alleviate the necessity for renegotiating elapsed contracts and for maintaining current status on the One Time Purchase contracts. These two areas will be discussed in an effort to offer an alternative automated approach to the present method of operation. The following discussion describes the input, data base, processing and output requirements of the two areas and propose an EDP system to satisfy the requirements. The input analysis considered the frequency of input, input media, format of the input and the type of transactions processed. The data base requirements considered the list of data elements, including whether the elements are alphabetic, numeric or alphanumeric and the format of the data base. In regard to the processing requirements, the study considered the type of operations required: searching, sorting and editing. Lastly, the output requirements consisted of the output media, format and the frequency of the output.

In the input analysis phase it was determined that there are two types of input which the contracting specialist must input to the system in meeting his responsibilities. The first input type is the maintenance and updating of each Indefinite Delivery contract. It was decided to use a timesharing schedule vice a batch schedule because any request for an Indefinite Delivery contract update occurs on demand and not all contracts require updating. The input media would consist of terminal displays which give the flexibility of rapid update of a record. The input format shown in figure 7 avoids having to display the entire record each time selected fields have to be updated. The transactions involved are the manipulations of selected field that the contracting specialist

may want to change is the "dollar amount" field. The second input requirement is the maintenance of the current status of One Time Purchase contracts. It is obvious that this function must occur on demand because different contractors provide status only on their contracts. Since there is no guarantee that all the status will be received simultaneously, it was decided that a time sharing demand input schedule would satisfy this requirement and the input media would be terminal display CRT units. The format of the input is similar to the format of figure 7. Normally, the only fields that would change are the estimated delivery date (EDD) and status fields.

CONTRACT NUMBER	FIELD TO BE UPDATED	FIELD TO BE UPDATED

TERMINAL DATA INPUT

Figure 7

The data base must be structured so that useful and understandable information required by the procurement division can be readily obtained. This is accomplished in two ways. For Indefinite Delivery contracts, the data base required is called the "Annual ID Contract" file and it's composition is Indefinite Delivery Contracts arranged in contract number order that are active in the current fiscal year. The format of the file is illustrated in figure 8 and the list of data elements contains the contract number, job order number, material or service provided, dollar amount allocated for the contract number and the

date the contract elapses. The contents of the fields in the file are both numeric and alphanumeric. For One Time Purchase contract status, the data base file is called the "OTP" contract file and consists of the following data elements: contract number, brief description of the requirements, status, job order number and dollar amount allocated. It's composition is shown in figure 9 and the contents of the file are alphanumeric and numeric.

The processing requirements must include the capability of sorting records by contract number, dollar amount, estimated delivery date, etc. In addition the ability to edit selected fields without displaying the entire record must be built into the system. The searching of the files is accomplished by direct access.

The output required by the procurement division must be in an easy-to-read form. There are two media for accomplishing this form. One is to have the display terminal output the status that management or the shop center requires immediately, however there is no hard copy capability with this media. A second media that supplies a hard copy capability would be a low or medium speed printer. There are various options for outputting the data; an example output for Indefinite Delivery Contracts is shown in figure 10. This output would list all contracts that would elapse in a specified number of days in contract number sequence. For One Time Purchase Contracts the format of the output is shown in figure 11 and would key on the dollar amount field and list only those contracts over a certain dollar amount. This would be valuable information if the procurement division was comtemplating

CONTRACT NUMBER	MATERIAL SERVICES PROVIDED	DOLLAR AMOUNT ALLOCATED	CONTRACT ELAPSE DATE	JOB ORDER NUMBER	CURRENT STATUS

INDEFINITE DELIVERY

CONTRACT FILE

Figure 8

CONTRACT NUMBER	DESCRIP. OF REQ.	CURRENT STATUS	DOLLAR COST ALLOC.	EST. DEL. DATE (EDD)	JOB ORDER NUMBER

ONE TIME PURCHASE

CONTRACT FILE

Figure 9

ELAPSE DATE: 20 June 1975

CONTRACT NUMBER	DOLLAR AMOUNT REMAINING	DESCRIPTION OF SERVICES
N3360-0213-4610	$5,000.00	Cement Finishing
N6430-4132-1965	50.00	Paint Removing
N7530-6145-1776	2,500.00	Electrical Wiring

SAMPLE DATA OUTPUT LISTING

Figure 10

BASE DOLLAR AMOUNT: $15,000.00

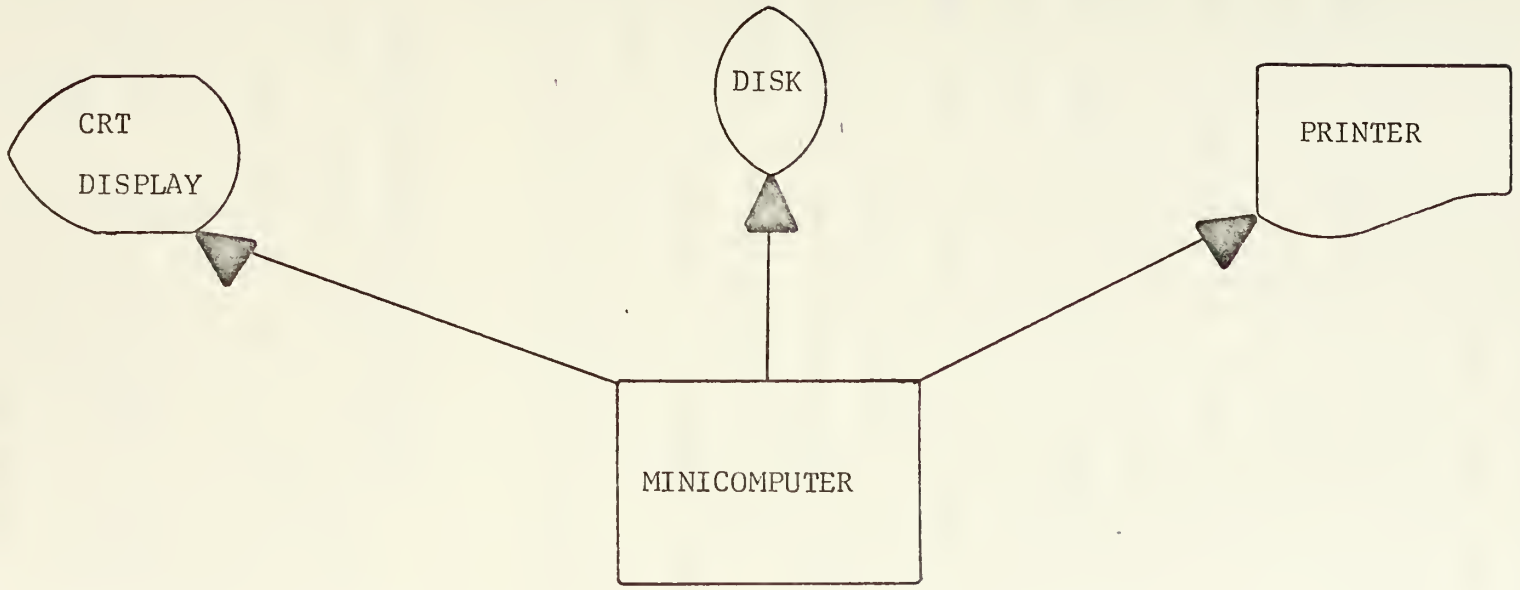
CONTRACT NUMBER	STATUS	DOLLAR AMOUNT	EDD
N3021-1245-6637	Shipped	$15,300	3 June 1975
N3366-2350-1976	Backordered	17,000	22 June 1975
N3366-2365-1876	Partial Shipment	18,000	22 June 1975
N6702-3051-1748	Delayed	17,330	19 June 1976

DOLLAR LIMIT DATA LISTING

Figure 11

cancelling some of the high value non-critical contract items in order to reprogram the money to order highly critical items.

To handle the above requirements a conceptual EDP system is shown in figure 12. The file organization structure needed to implement this system will be described in chapter five. The system would consist of a CRT display terminal, a low speed printer for allowing a hard copy capability, offline disk storage to rapidly bring files online for immediate status information and a minicomputer to sequence the operations of the other peripheral devices.



CONCEPTUAL EDP SYSTEM

FOR

PROCUREMENT DIVISION

Figure 12

IV. PROGRAM MANAGERS DIVISION

For every work request that NAVELEX Vallejo receives from a sponsoring activity, a program manager or project manager is assigned by NAVELEX to monitor the work request through to completion. The duties of a program manager include serving as the contact point for the receipt, coordination and correlation of customer program requirements, ensuring timely and efficient completion of task assignments, advising management of potential difficulties and delays in critical task assignments, determining time and cost trade-offs in meeting customer requirements, monitoring the progress of all assigned projects and preparing the necessary reports to management and directing distribution of funds for the accomplishment of assigned program tasks. The remaining portions of the chapter describe the program managers' present method of accomplishing his assigned duties and offer an alternative automated approach to improve the overall effectiveness of the operation.

A. PROGRAM MANAGER'S OPERATION

When a request for servicing some type of equipment is received from a sponsoring activity, NAVELEX assigns a program manager with expertise in the operation of that equipment to be in charge of the project. Once the program manager is assigned he must decide on the number of steps that are needed to complete the work request. Each step must be assigned a job order and given to a shop center where the shop center analyzes the number of personnel it

will have to supply, since the shop center actually does the work on the step. Any materials or services that the shop centers require are referred to the program manager who in turn has to consult with the procurement section to ascertain whether a contract exists or if bids are needed to establish a new contract. Determining that the contract exists (or after awarding new contracts) the program manager must wait for the status of the contracts. In some cases the materials for some of the steps will be received before other steps which could effect the completion of succeeding steps. The program manager must constantly be cognizant of the bottleneck that could occur. If the situation arises where the dollar amount of the required materials or services outweighs the dollar amount of the job order, the program manager must determine time and cost trade-offs in meeting the sponsoring activity's requirements. The alternatives available to the program manager are to request that the sponsoring activity increase the dollar allocation for the work request or to attempt to refurbish some of their old equipment to conserve money. If the work proceeds as scheduled, the material will be receipted for by the shop center and the paperwork passed on to the program manager who must provide a copy to the financial section so that the contractor can be paid.

The problem that the program manager faces with the above operation is to get status in a timely fashion of all outstanding contracts that may necessitate changing priorities. Presently, this is done manually be calling either the contractor or NSC Oakland for the current status of contracts. This interrogation may take two or three hours if the telephone lines are busy or if NSC Oakland has to query their computer because status has a low

priority in their computer operation. When this status is received it must be sent to the management personnel section in an understandable format so that time and trade-off considerations can be weighed and a decision reached on how to complete the assigned work request.

Analysis Of Conceptual EDP System

To alleviate or minimize the problem associated with the above operation an analysis of the present techniques of operation lead to the conclusion that the operation could indeed be automated. The succeeding paragraphs will analyze individually the input, processing, data base and output requirements, respectively. The components of the input requirements include the frequency of input, content of the input, i.e. whether the input is alphabetic, numeric or alphanumeric, time of input, input mode, format and the types of transactions. The processing requirements consist of searching, method of retrieval, editing and sorting. The data base requirements consist of the list of data elements, format of the data base and the data structure. Finally, the output requirements consists of the format, output mode, frequency of the output and the content of the output.

In the input requirement phase of the analysis, the data that the program manager must have to assist him in meeting his responsibilities consists of two types of input. The first type of input is the establishment of a record called the "Contract" record for each contract number (see figure 13). At the very minimum, the amount of information needed for creating the input for the "Contract" record is the contract number, a brief identification of the materials or services required and the dollar

amount allocated. The content of the input is both alphanumeric and numeric and the frequency of inputting this data is obviously on demand because awarding a contract to a bidder is directly related to the dollar amount of the bid. However, it is recommended that new "Contract" records only be established at the end of NAVELEX's daily operation and that it be accomplished as a batch process.

The second type of input that the program manager must have at his disposal is the ability to query the "Contract" records for status (see figure 14). The most important field to the program manager is the estimated delivery date (EDD). The only input that must be supplied by the program manager is the contract number. The frequency of input is the same as the first type of input with the exception that the information must be supplied as soon as it is needed so that the input mode must be realtime CRT terminals. The only type of transactions applied in the input phase of the analysis are editing different fields of the associated records.

The components of the processing requirements must be capable of allowing the program manager the ability to selectively search for status on "Contract" records. A sequential search would not be feasible if many records were on file, therefore the solution would be to have the capability of direct access. Since the status of a contract is constantly changing until the material is actually receipted the option of being able to update the record is required. This updating would include the editing of certain fields of the record if the status is changed or if a substitute item is exchanged for the original material. The third processing requirement is the capability of deleting recoreds from the file once the materials

CONTRACT NUMBER	IDENTIFY MAJOR EQUIPMENT	DOLLAR AMOUNT ALLOCATED	ADDITIONAL COMMENTS

ESTABLISHMENT

OF

CONTRACT RECORD

Figure 13

CONTRACT NUMBER	MATERIAL OR SERVICE IDENTIFICATION

CRT DISPLAY

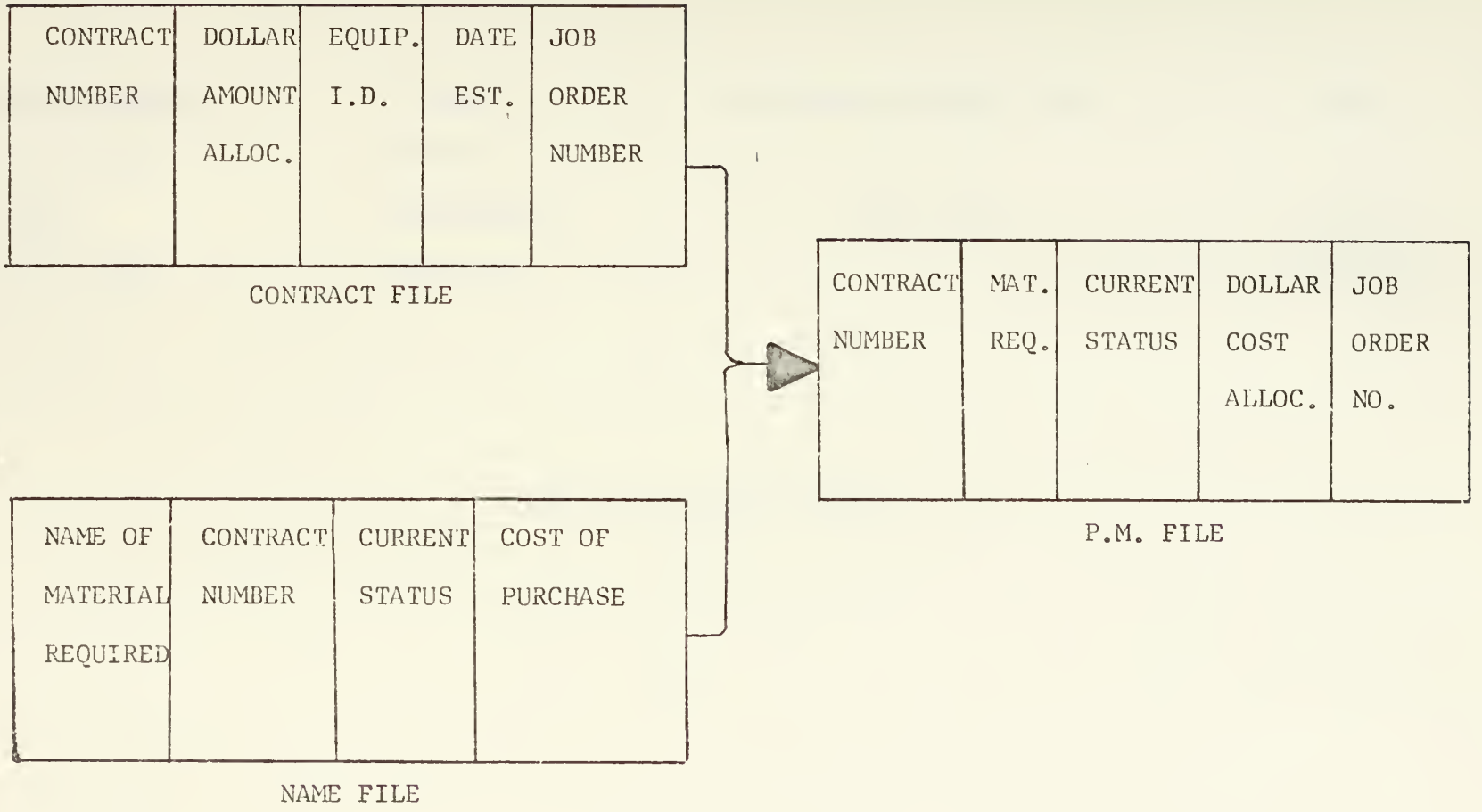
CONTRACT DATA

Figure 14

have been received. The retrieval mode for bringing records online would be direct access in order to speed up the computer time per request versus the slower sequential mode. The final requirement of sorting is a sequential sort keying on the contract number.

The data base required to satisfy the input and processing required would consist of two files called the Contract file and the Name file. The "Contract" file which is made up of "Contract" records has the composition of contract number, dollar amount alloeated, a brief identification of the major piece of equipment being refurbished and the date the eontract was established. The "Name" file contains identification of the material needed in the renovation of the equipment, contract number, current status, job order number and the cost of purchase. These files are then merged to create a master file called the "P.M." file with the format for these data structures shown in figure 15. The "P.M." file consists of the eontract number, a listing of the materials ordered under the contract number, status, and the cost allocated for the material.

The output information required by the program manager must be in a readable and usable form. There are two media for obtaining the required output. To keep management informed on the dollar cost and any delay in receiving materials, one type medium is to have a hard copy capability that is supplied by a line printer. This report would be presented to management on a weekly basis. An example output listing is given in figure 16 and would key on the contract number field listing the contract numbers in sequential order. To keep the program manager abreast of the ehanging status of materials ordered, the second medium that would be employed is a CRT display. Its format is similar to figure 17.



PROGRAM MANAGERS' DIVISION FILE MERGE

Figure 15

CONTRACT NUMBER: N36601-5245-1601

MATERIAL ORDERED	STATUS	ESTIMATED DELIVERY DATE	COST
FLEX SCREW	SHIPPED	3 June 1975	$ 50.00
FLANGE	BACKORDERED	April 1976	3,000.00
HEAT PLATE	RECEIVED		10,000.00

SOMPLE COMPUTER LISTING

Figure 16

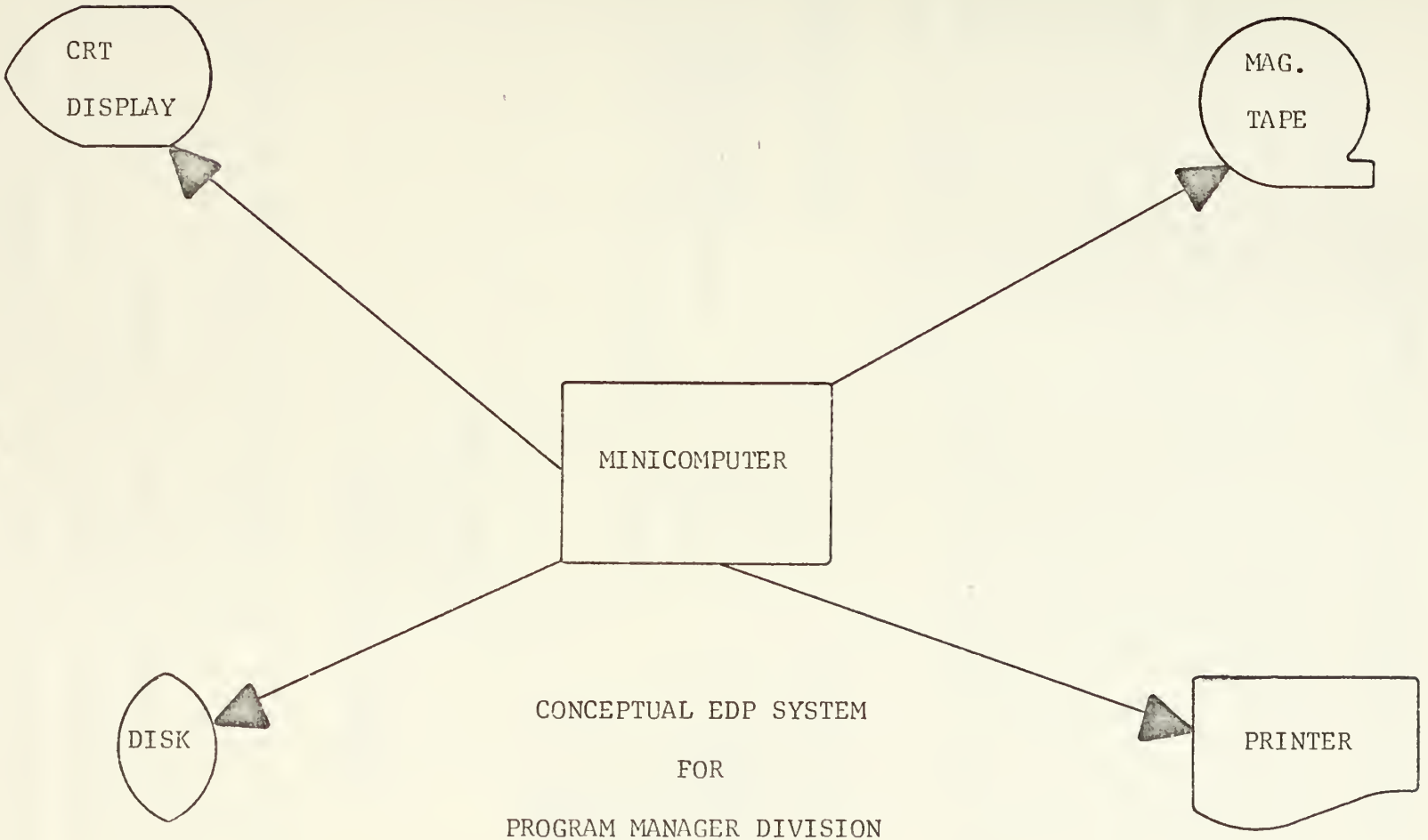
NAME OF MATERIAL: ELECTRICAL TRANSFORMER

STATUS	CONTRACT NUMBER	COST
Backordered EDD 20 June	N7431-5132-0961	$30,000.00
Shipped	N8431-0321-1947	15,250.00
Partial Shipment	N9321-0113-1948	13,946.00
Canceled	N9431-1123-1744	30,000.00

MATERIAL STATUS LISTING

Figure 17

Using the knowledge of the above analysis, a conceptual EDP system is depicted in figure 18. This operation would be based on only having the users trained in the operation of the CRT display. The file organizatinn associated with this system will be discussed in Chapter five. The system would require off-line storage versus loading magnetic tapes, it was decided to have the files stored on disk. A small minicomputer will be used to bring the monitor or supervisor program on-line (from magnetic tape) and to sequence the other peripheral devices. A medium or low speed printer is required to generate the weekly reports for management and a CRT display terminal would be used for creating new "Contract" records, editing files and deleting records. This would eliminate the need for a card reader.



CONCEPTUAL EDP SYSTEM

FOR

PROGRAM MANAGER DIVISION

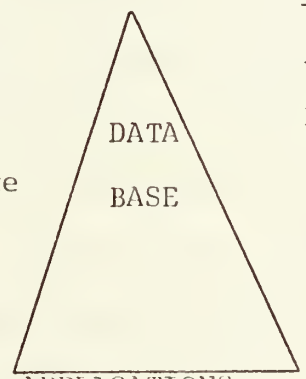
Figure 18

V. FILE ORGANIZATION & CONCEPTUAL EDP SYSTEM

In the earlier analysis of chapters two, three and four, each division's operation was treated as a separate entity and a conceptual EDP system was proposed for the various applications without regard to integrating the four basic components of systems analysis namely the processing mode, data base, file design and the applications required by the user. The triangular effect of these four components as they relate to the feasibility study is illustrated below:

Processing Mode

1. Batch
2. Remote batch
3. On-line retrieval/ Batch update
4. On-line retrieval/Update



File Design

1. Sequential
2. Indexed Sequential
3. Random
4. List Structure
   a) Uncontrolled length
   b) Controlled length
   c) Inverted

APPLICATIONS

1. Payroll
2. Contract File Inquiry
3. Contract File Update

The remaining sections of this chapter will discuss the following items: 1) review the data base files proposed for chapters two, three and four, 2) analyze the various processing modes mentioned above, 3) discuss the various file design considerations, 4) review the applications of the three divisions and determine a conceptional system and 5) provide criteria for evaluation of the

system and make recommendations for further research in determining the overall effectiveness of the system.

A. THE DATA BASE

The data base proposed for the financial division consists of the "Payroll," "Dictionary" and"Money" files. For the procurement division the files proposed consists of the "Annual I.D. Contract" and "O.T.P. Contract" files and finally the program managers division files consisted of the "Contract," "Name," and "P.M." files. The hierarchic data structure approach is used for the above mentioned files and is shown in figure 19 [Ref. 1]. The superior record in the hierarchy is called a master record and an inferior record is called a detailed record. In addition, a detail of one record may be a master of another record. The network schematic of the hierarchic file structure is illustrated in figure 20. For each file in the figure, a list of the data elements associated with that file are included. From examiniation, it is conceivable that the "Annual I.D. Contract" file and the "O.T.P. Contract" file, even though each is a master record, may be merged into a single master file because they contain the same data elements with the exception of the elements, "Contract Elapsed Date" and "EDD." Thus, the new merged file would contain seven elements vice the twelve data elements that now exist. In addition, other common data elements are employee name, social security number, contract number, status, material required, job order number and dollar amount. Although it is not presently known what file design will be used, these data elements are candidates for maintaining in a Key Directory described in a subsequent section.

Record Name	Record Type	Master of	Detail To	Contents
Payroll	Master	Dictionary Money		Hours worked, Pay earned, Employee's name, Social security number
Annual I.D. Contract	Master			Job order number, Contract number, Status, Contract elapse date, Dollar amount, Material or service
O.T.P. Contract	Master			Contract number, Job order number, Dollar amount, Current status, Description of req., EDD
Contract	Detail		P.M.	Contract number, Job order number, Date established, Equip. Identification, Dollar amount
Name	Detail		P.M.	Material required, Contract number, Current status, Dollar amount, Job order number
P.M.	Master	Contract Name		Contract number, Material required, Current status, Dollar amount, Job order number
Dictionary	Detail & Master	Money	Payroll	Employee's name, Social security number Rate of pay, Code (S or H)
Money	Detail		Payroll Dictionary	Job order number, Dollar amount, Number of hours worked, Social security number

HIERARCHIC DATA STRUCTURE

Figure 19

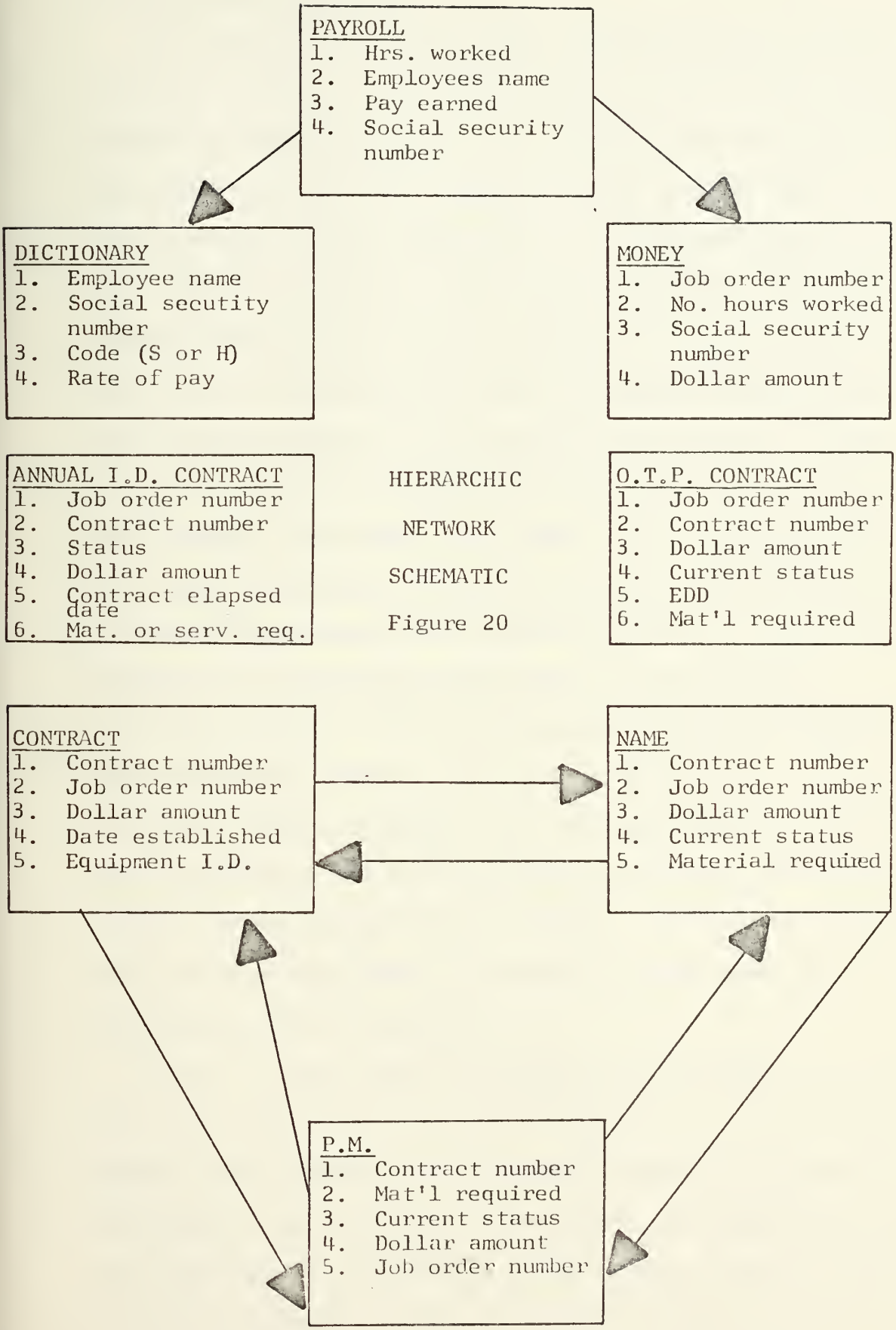

PAYROLL
1. Hrs. worked
2. Employees name
3. Pay earned
4. Social security number
DICTIONARY
1. Employee name
2. Social secutity number
3. Code (S or H)
4. Rate of pay
MONEY
1. Job order number
2. No. hours worked
3. Social security number
4. Dollar amount
ANNUAL I.D. CONTRACT
1. Job order number
2. Contract number
3. Status
4. Dollar amount
5. Contract elapsed date
6. Mat. or serv. req.
HIERARCHIC
NETWORK
SCHEMATIC
O.T.P. CONTRACT
1. Job order number
2. Contract number
3. Dollar amount
4. Current status
5. EDD
6. Mat'l required
CONTRACT
1. Contract number
2. Job order number
3. Dollar amount
4. Date established
5. Equipment I.D.
NAME
1. Contract number
2. Job order number
3. Dollar amount
4. Current status
5. Material required
P.M.
1. Contract number
2. Mat'l required
3. Current status
4. Dollar amount
5. Job order number

Figure 20

B. THE PROCESSING MODE

The different processing modes considered in the analysis consisted of batch, remote batch, on-line retrieval/batch update and on-line retrieval/update. In the strict batch processing mode, users prepare their programs, punch them on some input media such as cards and then submit them to an operator for execution. User programs are input to the computer in batch. The operating system software would read one program at a time into the machine and execute it according to some predetermined discipline and write out the results on some output device such as a printer. The operator would retrieve the printed output and return it along with the input card deck to the user. Thus, the user's only contact with the system is through a slot in the ADP section where he/she deposited cards and retrieved the output. This mode of operation is suitable for many types of production runs; i.e., processing against written and debugged programs that are used again and again. However, with this mode there is a time lag, or turnaround time, of anywhere from a couple of minutes to several days depending on the users distance from the EDP center and the computer center's system characteristics. Therefore, if response time is a critical factor in the user's requirements this mode of processing may not be adequate.

Within a remote batch processing mode environment, the user is physically remote from the computer facility. The user provides requests from terminals to run certain production programs in the batch mode at the EDP center. The output may be printed at the remote location of the user or at the computer center. As far as the user is concerned he has made direct contact with the central processing unit for his request. As far as the computer is

concerned,however, the request is treated in the batch processing mode. The reason for this difference in concept is that the request, once it leaves the terminal, is put in a job queue and processed according to some determined servicing discipline. This mode of processing is desirable for a user that does not own or have a computer center dedicated to his work requests and the output generated is not required immediately.

The on-line retrieval/batch update processing made consists of the user employing some on-line device such as a terminal to immediately seize the central processing unit and interrogate the data base directly. However, it any update to the data base is required, the user makes the request on the terminal, feeds the information to some off-line storage device (e.g., magnetic tape) and at the end of the day's operation this data is processed in a batch mode. This processing mode may be desirable if the user needs to retrieve thefiles on-line but file updating is not required as rapidly.

Finally, the completely on-line retrieval/update processing mode allows the user to seize the central processingunit and hold it until the inquiry or update is complete. This type of processing is sometimes called processing in real time. Real-time processing implies that the computer receives data, processes it, and returns results quickly enough for these results to be utilized in the continuation of the task being conducted. Many operation don't require an on-line update because the manager or supervisor is not going to be in a position to make an immediate decision on the basis of the output generated, so a batch update would suffice.

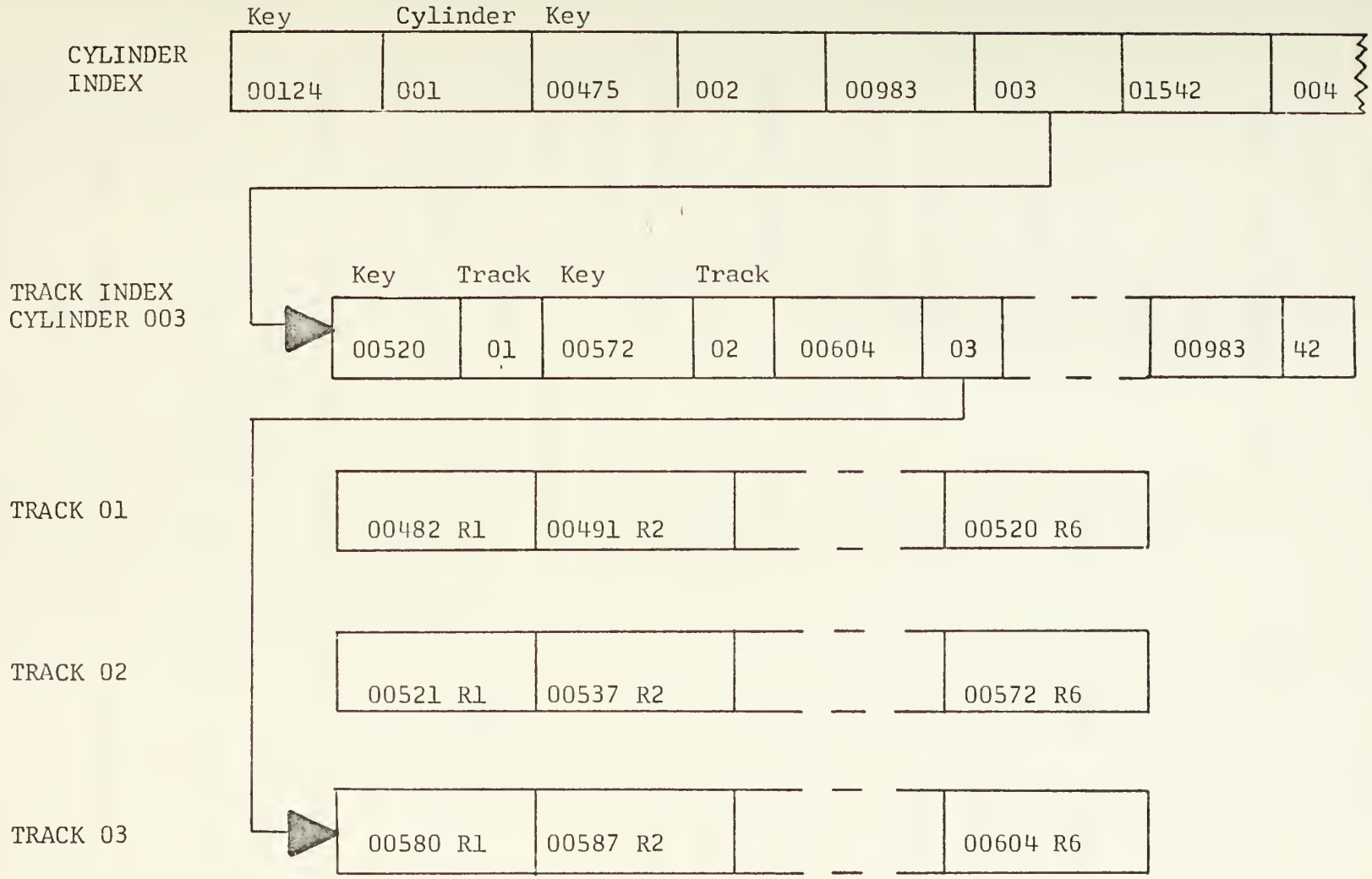
C. THE FILE DESIGN

There are many options available for file design, but for the purpose of this study the file designs considered consisted of sequential, indexed sequential, random, and list structures with emphasis on uncontrolled length, controlled length and inverted files.

With a sequential file design, the logical and physical order of the records are the same. Generally, the records in a sequential file are in lexicographic order of the values in some particular field or fields within the records. The fields that determine the sequential order are called keys. For instance if the field "Name" was a key the file would be ordered alphabetically. If a key is used in searching a file, it is relatively easy and quick to retrieve a number of records in sequence or to determine if a particular record is present in the system by performing a sequential search on the file using the key. For applications that require the use of a magnetic tape, the sequential file design is the only option that is open to the user because the magnetic tape can only be searched using one key at a time. The major disadvantage of a sequential file structure search lies in the fact that each and every record in the file must be examined if the search involves a field which is not the key for the file.

With an indexed sequential file design, records are stored in sequential order as on magnetic tape. However, an indexed sequential file design organization takes advantage of the cylinder structure of the particular direct access file to provide indexes that make it possible to locate a specific file record with only

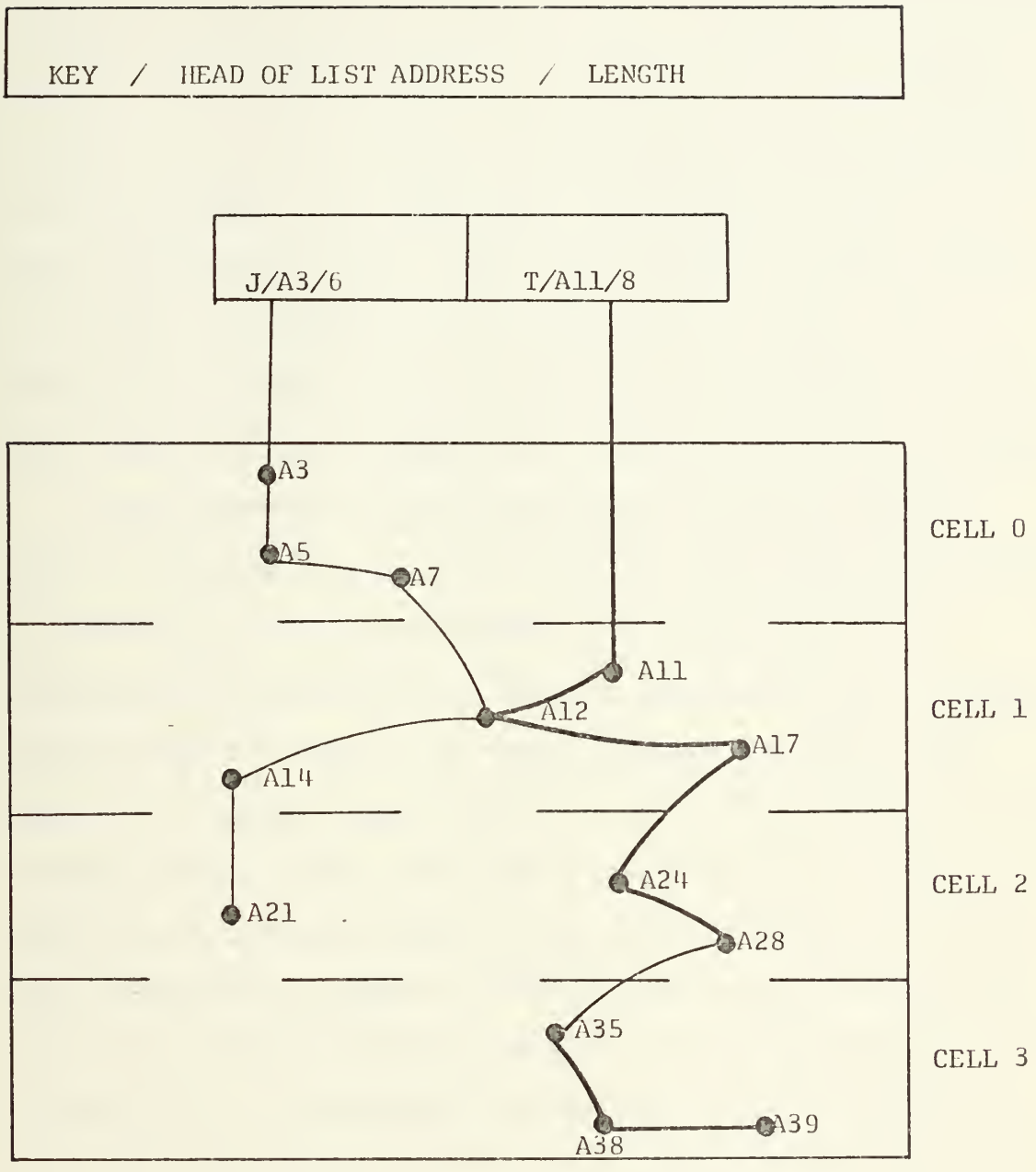
one seek delay. A two-level index is used. The first index is a cylinder index (e.g., a table containing the control key of the last record stored in each cylinder as the argument and the cylinder number as the function of the table) and the second level index is the track index (e.g., another table whose arguments are the control keys of the last record on each track and whose function values are the associated track addresses). An example of an indexed sequential file is illustrated in figure 21. When a file is in use, the cylinder index is maintained in main memory. If it is desired to find a record in figure 21 corresponding to the control key 00587, first, a table look-up on the cylinder index is performed with 00587 as the search argument, finding the first argument greater than or equal to 00587. Since 00587 is greater than 00475 and less than 00983 the record is determined to be in cylinder 003. Thus a seek is performed on cylinder 003 and its first track is read, placing the track index for cylinder 003 in memory. Again a table look-up is performed using 00587 as the search argument. This search reveals that the record is in track 03 of this cylinder, so one finds that the second record is the one that is desired. This whole procedure consists of a table look-up, one file seek, a read, another table look-up, another read, and examine the track to find the record. The advantage of this file design is that the time to find a record is not as great as with a sequential file design because only one seek is performed and the time involved in table look-ups is small. The disadvantage with this design involves the handling of additions to the file. Since the records are tightly packed into the file tracks, there is no room for new records unless extra space is provided.



INDEX SEQUENTIAL
FILE STRUCTURE

Figure 21

Generally, list structure file design techniques fall into two classes: multiple threaded lists (controlled and uncontrolled length) and inverted lists. In a multiple threaded list (uncontrolled length), there is a directory that contains a list of keys. In addition to the key name and value, a link address which indicates the first record on the direct access storage device (DASD) is also stored in the key field. The output of the key directory is a fixed length record containing the key/head of list address/list length. A sample multiple threaded list is shown in figure 22. The head of list address is represented symbolically as An, where n is a numeric representing a mass memory address. Records within the file area are represented as dots along the thread emanating from the output level of the key directory. Thus, the J list begins at address A3 and contains six records. As indicated in figure 22, the fourth record on the J list is also the second record of key T because of the list intersection. This record has not been labeled with an address in the figure because it is not a head of list record since the head of the T list is at A11; however, there would be a link address pointing to this record contained within the record at A11. If, then, a query conjunction JT were to be searched in this file, the Key Directory Decoder would decode both J and T and examine the respective list lengths at the output of the directory. Since the J list is shorter, containing six records as opposed to eight for the T list, the J list would be searched, thus requiring six random searches within the file area. Each accessed record must be examined in core for the joint occurence of T. With this type of file design a DASD must be used because



MULTIPLE THREADED LIST STRUCTURE

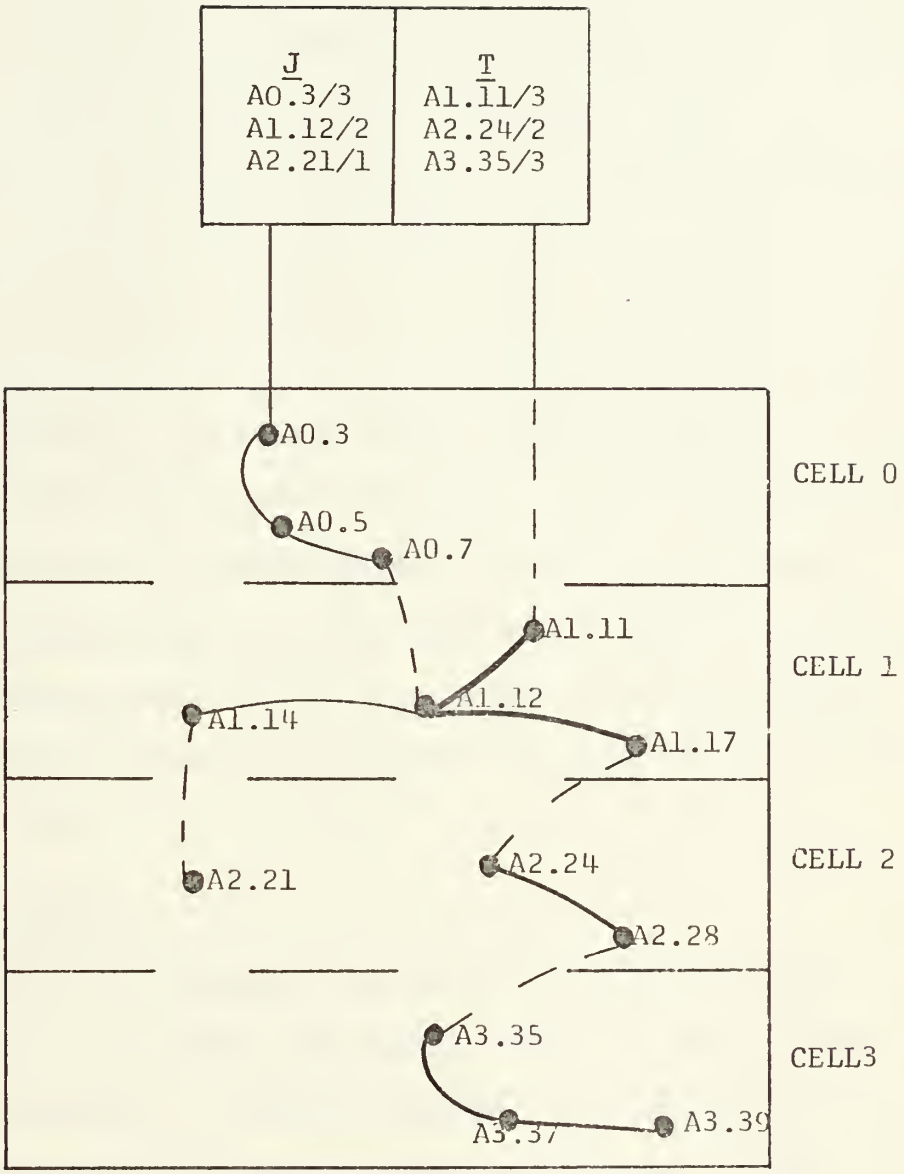
Figure 22

of the random searehes required. The greatest disadvantage of the multiple threaded list is that in order to respond to a eonjunetion of terms like J interseetion T, it must aeeess from the DASD and transfer to eore all reeords on the shortest list for examination in the proeessor, even though the interseetion of these lists, whieh satisfies the query, may be mueh smaller (in the example, six reeords are queried for one interseeted reeord). The principal advantages of the multiple list (uncontrolled length) file organization are programming simplicity and update flexibility.

In the inverted list file organization system, all link addresses have been removed from the file area and appear instead at the output of the key directory. This will result in a eonsiderably larger directory than the multilist system although the total memory usage is no greater because these same link addresses no longer appear within the file reeord. The lists are variable length reeords that must be maintained in a monotonie sequenee for efficient logieal manipulation. The seareh for the joint oecurrence of terms is aeeomplished by list interseetion within the direetory and the conjunetion of a nonnegated key with a negated key is accomplished by removing from the nonnegated key's list of addresses all those that appear on the negated list. Eaeh of the two deseribed logieal funetions are greatly expedited if the list addresses are stored in monotonie sequence, since only a single pass through the two lists is required. The prineipal advantages of the inverted list over the multilist file organization is that the list interseetion or merge proeess is considerably more efficient since it is performed on eompaet, sequeneed lists rather than requiring a random aecession for each

record on the list. Also, it is a good file organization for data retrieval, especially when it is not known in advance what keys the user will require to process data. The disadvantages of the inverted list system are that a working or staging area is required in order to perform the logic processing and the list records, being variable length, should include some reserve if real-time updating is to be allowed.

When discussing the multilist (controlled length), it should be noted that multiple lists (uncontrolled) and inverted file organization are special cases of multilists where the former has list control of infinity and the latter has list control of unity. Thus, controlled length multilists are actually partially inverted files. The special case of controlled length multilists considered in this study is the cellular partition file design. The basis of the cellular partition is to define logical cellular boundaries throughout the DASD medium into which the records may be placed according to some predetermined storage strategy. A sample cellular multilist file organization is shown in figure 23 with the predetermined length being three. Since the cell is part of the record address, the address notation Am.n/L is used where "m" identifies the cell in which a given lists begins, "n" identifies the mass memory address and "L" identifies the length of the record. Consider the query JT. An examination of the output level of the directory shows that list J contains sub-lists that are wholly contained with Cells 0, 1, 2 and list lengths 3, 2 and 3; therefore, one cannot expect to find a conjunction of J and T in any cells that are not contained within the cell intersection between the head of list addresses of J and T.



CELLULAR PARTITION

FILE STRUCTURE

Figure 23

That is, list J contains a head of list address in Cell 0 but list T does not; therefore, no intersection of JT exists in Cell 0 because list T does not appear in Cell 0. Similar reasoning applies to Cell 3. Therefore, the search on the conjunction JT would be limited to those sublists J and/or T contained only in Cells 1 and 2; furthermore in Cell 1, either list J or T may be searched because they are the same length however, in Cell 2 list J is preferred because it has a length of 1 versus list T whose length is 2. The search would issue an I/O command against both addresses in the J listing. The entire search would be effected in three random accession times rather than six. The advantages of this file design are that random access can overlap (if permitted by the DASD configuration) provided the "next records to be accessed" are in different cells and the programming of this structure is no more difficult than the programming required for the multiple (threaded) list.

D. APPLICATIONS

A review of the applications of the financial division indicated that the payroll application was the only one that should be automated in the near future. This application consisted of updating the master payroll file weekly in order that the magnetic tape could be sent to NSC Oakland. For this application a batch mode should be utilized because there is no requirement for frequent inquiries to the file nor is the speed of response time a critical factor. It is further recommended that the "MONEY" file (figure 2) be designed as a sequential file because file access is generally for a group of records vice a

single record and these accessed records are copied onto magnetic tape for submission to Oakland.

The procurement division's applications consisted of updating and demand query of certain fields of the "Annual I.D. Contract" and "O.T.P. Contract" files. Since inquiry to these files is primarily on demand and then for only selected records, some configuration of an on-line random access file system is indicated. It is recommended that an on-line retrieval/batch updating system be utilized for this application since the user will be interested in the current status of various records. If the records require updating the user would generally not be in a position to make an immediate decision on the update information, even if it was done on-line, hence a batch update mode is recommended. Most of the fields of the "Annual I.D." and "O.T.P. Contract" files will not require key dictionaries but the keys that do require key dictionaries will have to be detailed (e.g., the keys of the dollar amount field may be broken down for every one-hundred dollars). Thus it seems obvious to use a fully inverted list for this reason. However, on closer inspection one finds that the disadvantages associated with this file design as mentioned above would negate any advantage that existed with using an inverted file structure organization. Thus, the file design recommended is the multilist (Cellular partition), with this design the advantage of an inverted list exists without the problem of requiring additional work space as required with a fully inverted list.

Finally, the only application for the program managers division that requires automation is demand inquiry of the "Contract" and "Name" files. With this application, fast response time is

important, therefore, some on-line random access file system is required. Since the program manager's division application is the same as the procurement division (with the exception of updating) it is recommended that the same system be incorporated for the program manager's division.

The results of the analysis indicate that the system should operate in two modes. At the top level of operation, there is an on-line system communicating with user terminals and vice versa. At the lower level there is the batch system for updating records and files on a predetermined schedule arranged by NAVELEX. Two file design organizations are maintained namely, sequential and multilists (Cellular partitions). The system shown in figure 24 encompasses all the hardware required to perform the applications of the three divisions into one system for NAVELEX.

E. EVALUATING CRITERIA

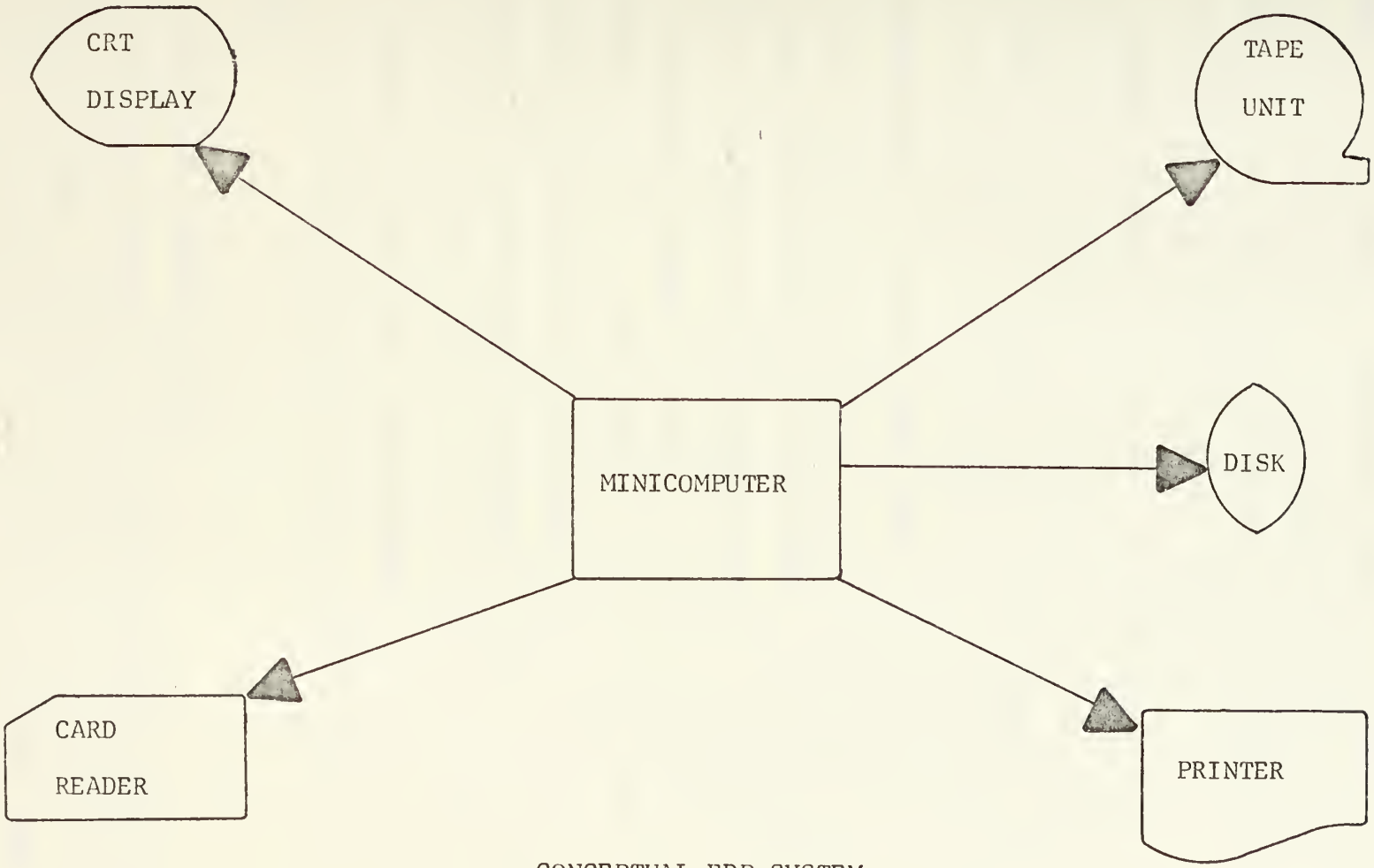
To further evaluate the computer system and file organization proposed, one must consider a set of performance and cost factors. The performance criteria that should be considered are recall ratio, precision ratio, coverage and response time and of these the most important factors are recall and precision. The recall ratio is defined as:

$$\frac{\text{number of relevant documents retrieved by the system}}{\text{total number of relevant documents contained in the system}}$$

and the precision ratio is defined as:

$$\frac{\text{number of relevant documents retrieved by the system}}{\text{total number of documents retrieved by the system}}$$

Although response time is important it must be a secondary consideration to precision and recall. Finally the coverage that the system provides is important because presumably, a user will not



CONCEPTUAL EDP SYSTEM

FOR

NAVELEX

Figure 24

even approach the system unless he feels that its coverage is such that it will be able to contribute to satisfying his information needs. However, comprehensiveness of coverage is really only of concern to the user who requires high recall and the requestor with a low recall requirement on the other hand, may not be particularly concerned about coverage.

The cost factors that have to be considered are the computer time used in searching and the frequency of use of the system. In machine terms the computer time used will depend on the size of the data base, the type of search (e.g., serial, inverted) and the number of records found. One point to note here is that the time taken in search with an inverted file system increases in almost direct proportion to the number of records in the query, whereas the effect of each additional record on speed of search in a sequential system is normally less than the effect of the inverted system. If the frequency of use of the system is great the net overall cost of the system goes down. It should be noted here that if too many users are allowed access to the system, it may become saturated and give slow turnaround time thereby discouraging potential users. By considering the above criteria, the system chosen will likely be more compatible with the user's needs.

F. ADDITIONAL STUDIES REQUIRED

The system presented is by no means specific to the tailored needs of NAVELEX. Additional research should be done to determine if a new file design would be required in the future. This may be accomplished by questioning the users on the expected frequency

of file inquiries or what new capability should be developed to meet future needs. It should be noted that with each new capability some amount of complexity is going to be introduced in maintaining any complex file design. Another method of reviewing and projecting new demands on the system is to do a statistical analysis of the frequency that data fields are accessed to ascertain if the present file system needs to be modified. Finally, a study should be initiated to determine if NAVELEX should buy pre-packed routines for their system or do their own in-house software development. There are trade-offs with this approach namely, if a pre-packaged routine is purchased, the user doesn't have to be proficient in the software language. On the other hand modification of the programs by the user may be very difficult. Obviously more studies are required before NAVELEX actually aequires a data base management system and it's associated operating system. It is hoped that the proeedures described in this paper will provide useful guidanee to NAVELEX in the development of automated data processing systems.

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